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A NUMERICAL METHOD FOR THE CALCULATION OF BELT CONVEYOR LENGTHS AS A FUNCTION OF THE INSTALLED POWER

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A NUMERICAL METHOD FOR THE CALCULATION OF BELT CONVEYOR LENGTHS AS A FUNCTION OF THE INSTALLED POWER

by

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ABSTRACT

This report presents an analytical relationship between the coefficient of terminal friction and the length of a conveyor. On the basis of a standard method for calculating the conveyor resistance to motion, the formula for calculating the maximum permissible length of a conveyor has been derivated. A Fortran program of this analysis is included, which will enable a rapid calculation of conveyor belt lengths. The relationship between conveyor length, capacity, velocity, power and inclination have been investigated using the method of analysis described and these results are presented in both tabular and graphical form.

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MÉTHODE NUMÉRIQUE POUR CALCULER LA LONGUEUR DES CONVOYEURS À COURROIE COMME FONCTION DE LA PUISSANCE INSTALLÉE

par

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RÉSUMÉ

Le présent rapport présente la relation analytique entre le coefficient de frottement et la longueur d'un convoyeur. À l'aide d'une méthode classique de calcul servant à déterminer la résistance du convoyeur par rapport au mouvement, on a dérivé une formule permettant de calculer la longueur maximale permissible d'un convoyeur. Cette analyse est disponible sous forme de programme Fortran dans le rapport. Ce programme permet donc de calculer rapidement la longueur des convoyeurs à courroie. La relation entre la longueur des convoyeurs, la capacité, la vitesse, la puissance et l'inclinaison ont été étudiées à l'aide de cette méthode d'analyse, et les résultats obtenus sont présentés sous forme de tableaux et de graphiques.

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INTRODUCTION

When designing an overland conveying system consideration must be given to the maximum permissable length of a single flight.

At present this evaluation is often left to the vendor, because the user or purchaser does not have sufficient background or knowledge on this subject. Although the assistance of a conveyor manufacturer is very valuable, the user should basically make his own estimation based on his system requirements. The need, therefore, arose for a quick method to calculate the permissable length of the belt conveyor as a function of the power installed. In order to estimate the length of an inclined conveyor tedious calculations are required. In this case the length is calculated using a method of subsequent approximation because the necessary coefficients are a function of the length itself.

To assist engineers and operators in the mining industry in the selection of conveyor belts a computer program has been developed which will enable a rapid calculation of conveyor belt lengths. The results of this analysis are presented in both tabular and graphical forms.

AN ANALITICAL SOLUTION FOR A CONSTANT FRICTIONAL COEFFICIENT AS A FUNCTION OF CONVEYOR LENGTH

The general equation for any given conveyor length can be written in the form:

$$a_2LC + a_1L + a_o = 0 \qquad (1)$$

where:

L	-	length of the conveyor belt
a_2, a_1 and a_o	-	coefficients of the polynomial
C	-	coefficient of terminal friction

The factor C, is used as a means of including the constant frictional losses which are independent of belt length and which are commonly spoken of as the terminal friction.

They include power absorption from skirting friction, moving tripper, acceleration of load etc.

Relationship (1) was developed on the basis of laboratory and field investigations and this data is shown in tabular form elsewhere (1).

The exponential equation C = f(L) can be solved only by iterative methods. However, a simplified solution may be obtained by analyzing the relationship between CL and L, which is shown on Figure 1.

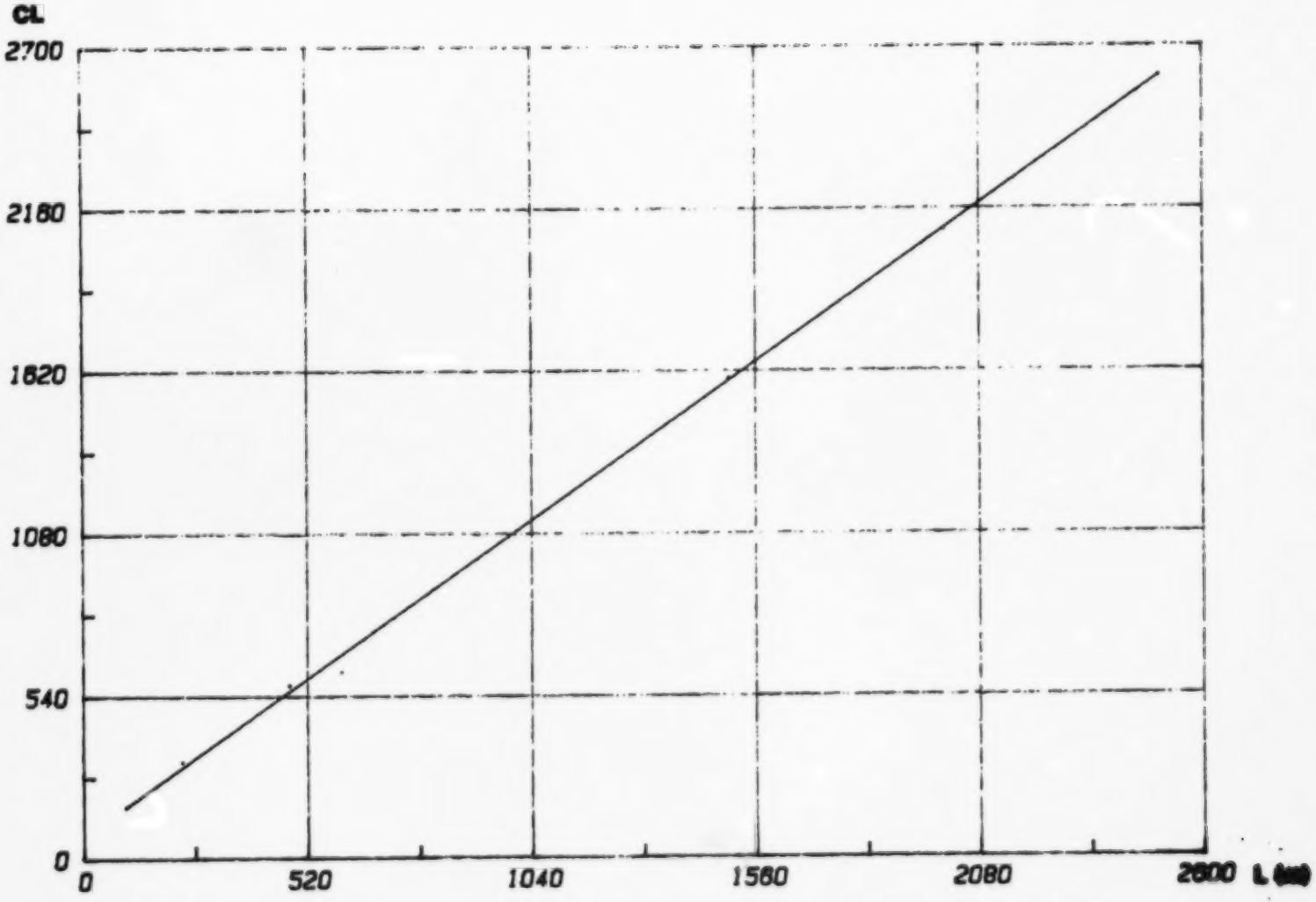

Fig. 1 - Relationship CL = f(L)

Regression analysis of these data indicated that the product LC could be expressed in terms of the factor C. The coefficient of correlation for the best fit line given by equation 2 is 0.992.

$$CL = 69.52 + 1.011L \quad (m) \tag{2}$$

Hence, this gives a very good estimate of the expected value of CL.

EQUATION FOR CONVEYOR BELT LENGTH

In practical applications a conveyor belt can be;-

a) horizontal,
b) inclined (angle of inclination is equal constant) (Fig. 2),
c) compound (horizontal and inclined) (Fig. 3).

For the purpose of this work on angle of inclination (of conveyor belt) for case (b) is assume α and for case c α`.

The general formula for the total power required of the driving pulley is:

$$N_c = \frac{vPu}{1000\eta_m} \quad [kW] \tag{3}$$

where v - belt speed (m/s),
Pu - total resistance to motion of the conveyor belt (N),
η_m - mechanical efficiency of the power train.

Fig. 2 - Incline Conveyor.

Fig. 3 - Compound Conveyor.

The total resistance to motion of the conveyor is:

$$Pu = LC\ f\ g\ \left(2B\ m_t + \frac{z_g\ m_g}{lg_s} + \frac{z_d m_d}{lds} + \frac{k_n k_z Qm}{V}\right)\ \cos\alpha + \frac{\mu_o\ Q_m^2\ g\ Lo\ k_n^2 K_z^2}{g\ V^2\ B_o^2}$$

$$+ k_2\ \ k_n\ \ Q_m\ \ V + L\ \ g\ k_2 k_n \frac{Q_m}{V}\ \ \sin\alpha \qquad (4)$$

where:

- L - conveyor length (m);
- C - coefficient of terminal friction
- f - friction coefficient (composite friction factor)
- B - width of the belt (m)
- m_t - mass of belt per unit length (kg/m^2)
- Zg, Zd - number of idlers per troughing set, and per lower idler set
- lg_s, ld_s - average idler spacing in upper and lower strand
- k_n - correction coefficient for conveyor incline
- k_z - capacity coefficient
- Q_m - mass flow rate (kg/s)
- V - belt speed (m/s)
- α - angle of inclination (rad)
- μ_o - coefficient of friction between conveyed material and skirtboards
- L_o - skirtboards length (m)
- B_o - skirtboards width (m)
- ρ - mass density of conveyed material (kg/m^3)
- m_g, m_d - mass of the revolving parts of troughing and return conveyor idlers (kg).

The final expression for conveyor length takes on the form:

$$L = \frac{A^* - bC^*\cos\alpha - k_n\ k_z(bD^*\cos\alpha + E^*) - k_n^2\ k_z^2\ F^*}{a\ C^*\cos\alpha + k_n - k_z\ \frac{D^*}{f}\ (af\cos\alpha + \sin\alpha)} \qquad (5)$$

where

$$A^* = \frac{1000\, N_c\, \eta_m}{V} \quad [N] \tag{6}$$

$$C^* = 9.81 f \left(2Bm_t + \frac{z_g m_g}{l g_s} + \frac{z_d m_d}{l d_s}\right) \left[\frac{N}{m}\right] \tag{7}$$

$$D^* = 9.81 \frac{Q_j f \rho}{3600} \left[\frac{N}{m}\right] \tag{8}$$

$$E^* = \frac{Q_j V_\rho^2}{3600} \quad [N] \tag{9}$$

$$F^* = \frac{\mu_o Q_j^2 \rho - 9.81 L_o}{6.48 \quad 10^6 \quad B_o^2} \quad [N] \tag{10}$$

On the basis of equation (5), a Fortran program has been written. The listing or Fig. 4 provides the details of the program design.

The required data are entered in the following order:

η_m, g, ρ, μ_o, L_o, f, m_t, z_g, z_d, l_{ds}, l_{dg}, B, α, m_g, m_d, Q_j, N, V, k_z, b_o

Fig. 5 shows the output when this program is run with a set of input values characteristic of a conveyor belt with an installed power of 200 kW.

It can be seen that the program calculates the conveyor length as a function of the angle of inclination and capacity coefficient. The output in this form can be very useful for a designer of conveyor transportation systems. Figs. 6, 7, and 8 show graphical representations of the results (nomogram).

The branches of this nomogram can refer to the following quantities:

1. Power N; in the case where the head station permits power to be added (Fig. 6), then V = const and K_2 = const.
2. Belt speed V; if it is possible to vary the conveyor's speed, then N = const and k_2 = const. (Fig. 7).
3. Capacity coefficient k_2; when conveyor receives material from a discontinuous system, then N = const and V = const. (Fig. 8).

```
c This program is read in data and do the calculate. The results will
c be print out in a table

      real nm,g,s,uo,lo,f,mt,zg,zd,lds,lgs
      real b,alfa,mg,md,qj,n,v,kz,bo
      character*20 input

      print*,'Enter the name of the data file:'
      read 99,input
 99   format (a)
      call data(input,nm,g,s,uo,lo,f,mt,zg,zd,lds,lgs,
     $                b,alfa,mg,md,qj,n,v,kz,bo)

      stop
      end


      subroutine data(input,nm,g,s,uo,lo,f,mt,zg,zd,lds,lgs
     $                      b,alfa,mg,md,qj,n,v,kz,bo)

      character*20 input
      real nm,g,s,uo,lo,f,mt,zg,zd,lds,lgs
      real b,alfa,mg,md,qj,n,v,kz,bo
      real l(20)

      open(unit=2,file=input,status='unknown')
      read(2,*,end=999),nm,g,s,uo,lo,f,mt,zg,
     $                  zd,lds,lgs,b,alfa,mg,
     $                   md,qj,n,v,kz,bo

      an=1.11
      bn=69.52

      type*,nm,g,s,uo,lo,f,mt,zg,zd,lds,lgs,
     $      b,alfa,mg,md,qj,n,v,kz,bo
      type*,' '
      type*,'                B =',b
      type*,'               Qj =',qj
      type*,'                N =',n
      type*,'                V =',v

      as=1000*n*nm/v
      cs=9.81*f*(2*b*mt+zg*mg/lgs+zd*md/lds)
      ds=9.81*qj*f*s/3600
      es=qj*v*v*s/3600
      fs=uo*qj*qj*s*9.81*lo/(6.48*(10**6)*b*b)
      type*,'        0.3     0.4     0.5     0.6
     $     0.7    0.8     0.9     1.0'

      do 20 i=0,20
      j=1
      ai=3.1416/180*i
              do 10 t=0.3,1.00,0.1
              t1=bn*cs*cos(ai)
              t2=t*kz*(bn*ds*cos(ai)+es)
              t3=t*t*kz*kz*fs
              b1=an*cs*cos(ai)
              b2=t*kz*ds/f*(an*f*cos(ai)+sin(ai))
              l(j)=(as-t1-t2-t3)/(b1+b2)
              j=j+1
 10           continue
      print 200,i,(l(j),j=1,8)
200   format(' ',i4,3x,8f8.2)
 20   continue
```

Fig. 4 - Fortran program design for a calculation of belt conveyor length as a function of installed power.

```
 r table
0.9000000        9.810000        1800.000        0.3500000        2.000000
2.8000001E-02    7.100000        3.000000         2.000000        5.000000
 1.250000        1.000000        5.000000         10.00000        21.70000
 398.0000        200.0000        2.000000         1.000000       0.8000000

                B =   1.000000
               Qj =   398.0000
                N =   200.0000
                V =   2.000000
      0.3      0.4      0.5      0.6      0.7      0.8      0.9      1.0
 0  2698.78  2261.70  1943.32  1701.02  1510.42  1356.53  1229.66  1123.24
 1  2053.27  1671.32  1406.64  1212.37  1063.69   946.22   851.05   772.36
 2  1657.37  1325.69  1102.51   942.05   821.11   726.66   650.86   588.66
 3  1389.83  1098.81   906.76   770.50   668.80   589.97   527.06   475.69
 4  1196.99   938.49   770.25   651.99   564.31   496.70   442.96   399.21
 5  1051.44   819.23   669.65   565.24   488.20   429.02   382.11   344.02
 6   937.72   727.07   592.47   499.00   430.31   377.68   336.06   302.32
 7   846.44   653.74   531.39   446.80   384.81   337.42   300.01   269.73
 8   771.58   594.03   481.88   404.60   348.11   305.01   271.03   243.55
 9   709.09   544.47   440.94   369.80   317.90   278.36   247.23   222.08
10   656.17   502.69   406.53   340.62   292.61   256.08   227.35   204.15
11   610.77   467.01   377.22   315.80   271.13   237.18   210.49   188.96
12   571.43   436.19   351.96   294.44   252.67   220.94   196.02   175.93
13   537.01   409.32   329.97   275.88   236.63   206.85   183.48   164.64
14   506.65   385.68   310.67   259.60   222.58   194.52   172.50   154.76
15   479.69   364.73   293.59   245.21   210.18   183.63   162.81   146.04
16   455.59   346.05   278.38   232.41   199.14   173.95   154.20   138.31
17   433.94   329.29   264.75   220.95   189.27   165.29   146.51   131.39
18   414.37   314.18   252.47   210.63   180.39   157.51   139.59   125.17
19   396.62   300.49   241.35   201.29   172.36   150.47   133.34   119.56
20   380.44   288.03   231.25   192.81   165.07   144.09   127.67   114.46
```

Fig. 5 - The output of the program.

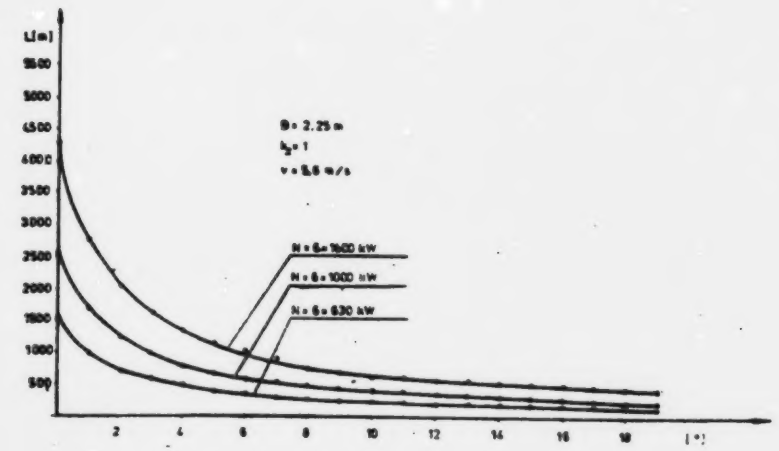

Fig. 6 - Example of the nomogram L = f(α) for V = const and k_z = const.

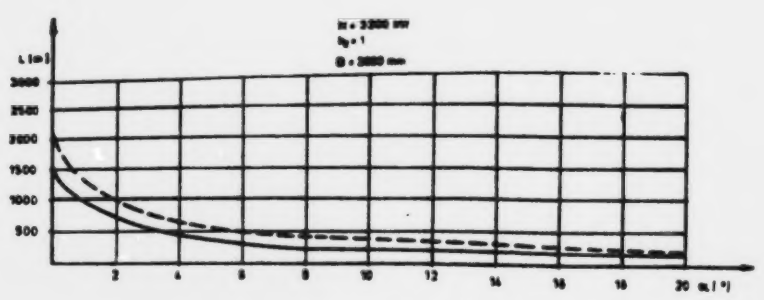

Fig. 7 - Example of the nomogram L = f(α) for N = const and k_z = const.

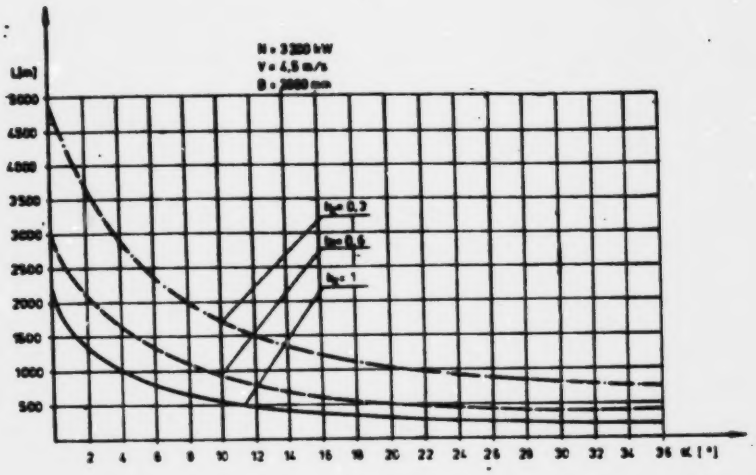

Fig. 8 - Example of the nomogram L = f(α) for N = const and V = const.

CONCLUSIONS

1. The presented method enables a rapid calculation of the maximum conveyor belt length as a function of power installed.

2. The method of computation can be expressed in the form of nomograms in which particular branches reflect the following quantities: installed head drive power N, belt speed V and capacity coefficient k_2.

3. The developed method can be very useful tool during the analysis of conveyor transportation system with different constructional parameters.

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